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THE TRANSMISSION OF TWO PROGRAMMES FROM BAND II FM TRANSMITTERS: an assessment of 'storecasting'

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Summary

After a general discussion of the transmission and reception, by means of a subcarrier, of a subsidiary programme ('storecasting') from Band II f.m. transmitters, the results of three field trials are given. For two of the trials the main programme was monophonic, whereas for the third it was stereophonic. The subsidiary programme was monophonic for all three trials.

It was found that, when using a 67 kHz subcarrier, the subsidiary programme could be radiated without causing undue impairment to main-programme reception for the great majority of present-day listeners, provided the main programme was monophonic. When the main programme was stereophonic, however, the subsidiary programme was found to cause severe impairment to main-programme reproduction by the majority of current stereo receivers.

The quality of reproduction of the subsidiary programme was only briefly examined, but it was concluded that it would be inferior to that of the main programme, particularly if it were to be received in the presence of a stereophonic main programme, either now or at some time in the future.

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THE TRANSMISSION OF TWO PROGRAMMES FROM BAND II F.M. TRANSMITTERS: AN ASSESSMENT OF 'STORECASTING'

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1. Introduction

The pressure for an increasing number of sound programmes makes it desirable to ensure that available broadcasting bands are fully utilised. VHF f.m. sound broadcasts, in particular, use a large bandwidth to provide a very high-quality service and, as complex circuits and techniques become more commonplace in domestic receivers, it is pertinent to consider whether or not further services may be added to a standard transmission without significant degradation to reception of the main programme. Although various proposals have been made, ranging from eight additional sound programmes to the transmission of a graphic display with speech accompaniment (in addition to a stereophonic main programme in both cases),[1,2] it is desirable as a first step to restrict discussion to the simpler proposals for one additional sound channel.

Whilst it may be feasible to devise an additional service that causes negligible impairment to main-programme reception, given suitable receivers at favourable receiving sites, the additional service may cause severe impairment when using receivers that were not designed with its presence in mind or that are used at sites that are subject to, say, multipath propagation, adjacent-channel interference, or fringe-area field-strength. It is therefore important, before adopting such a service, to assess its compatibility with main-programme reception using existing domestic receiving installations. This can best be done by means of a field trial involving a high-power transmitter that is currently providing a v.h.f. f.m. broadcast service.

This Report describes a series of field trials from the Radio-4 v.h.f. f.m. transmitter at Wrotham (93·5 MHz), carried out to study the effect of adding a second sound programme to an existing v.h.f. broadcast programme. The work was conducted mainly to assess compatibility with main-programme reception but a few assessments were also made of the quality of reproduction of the subsidiary programme when the main programme was monophonic. The system tested is described in the next section.

2. System under test

The system tested was one that has been in use in the USA for several years.[3,4] Known in the USA as 'storecasting' or 'S.C.A.',* it provides a subsidiary programme which, reproduced on receivers leased by the transmitting stations, is used mainly for background music in shops, restaurants, etc.[5] The system uses a subcarrier, frequency-modulated by the subsidiary programme, that is added to the main baseband programme signal; the whole is used to frequency-modulate the main carrier.

The choice of suitable parameters for the system involves several compromises.[6] The amplitude of the subcarrier used for the subsidiary channel should be small enough (relative to the amplitude of the main programme) not to cause cross-talk into the main programme, yet large enough to provide an adequate signal-to-noise ratio for the subsidiary programme. Similarly, the frequency of the subcarrier should be high enough not to cause interference to main-programme reception, yet not too high because of the cross-talk into the main-channel programme that occurs if the subcarrier approaches the extremes of the receiver i.f. passband. Too high a subcarrier frequency also tends to degrade the signal-to-noise ratio of the subsidiary channel and to introduce adjacent-channel interference problems. The bandwidth occupied by the subsidiary-channel signal should also be small enough for it not to interfere with main-programme reception, yet be sufficient to provide adequate quality of reproduction of the subsidiary programme. An interesting survey of the extent to which these compromises are successful under favourable reception conditions is given in Reference 7.

The majority of the parameters used for the field trials described in this Report were chosen to be the same as those adopted in the USA, not only for reasons of international standardisation but also because, from the experience gained in the USA, it was assumed that the parameters used there represented the optimum with regard to compatibility, subsidiary-channel performance, adjacent-channel interference, and receiver design. Because the majority of receivers in current use in the UK were not designed to operate in the presence of the subsidiary-channel subcarrier, however, and hence may differ in their performance from those in current use in the USA, it was decided to assess the effect of using either of two subcarrier frequencies for the subsidiary programme at various levels of injection,* all other parameters being the same as those adopted in the USA.[3] The field trials are described in the next section.

3. Field trials

3.1. General

The trials were conducted according to the sequence shown in Table 1.

Fig. 1 shows the arrangements adopted at the transmitter to inject the subsidiary-channel subcarrier.

Questionnaires were supplied to members of BBC engineering staff who were asked to report on reception of the main programme, using their home receivers, at the

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* Subsidiary Communications Authorisation.

* The level of injection is the peak deviation of the main carrier by the subcarrier, expressed as a percentage of 75 kHz.

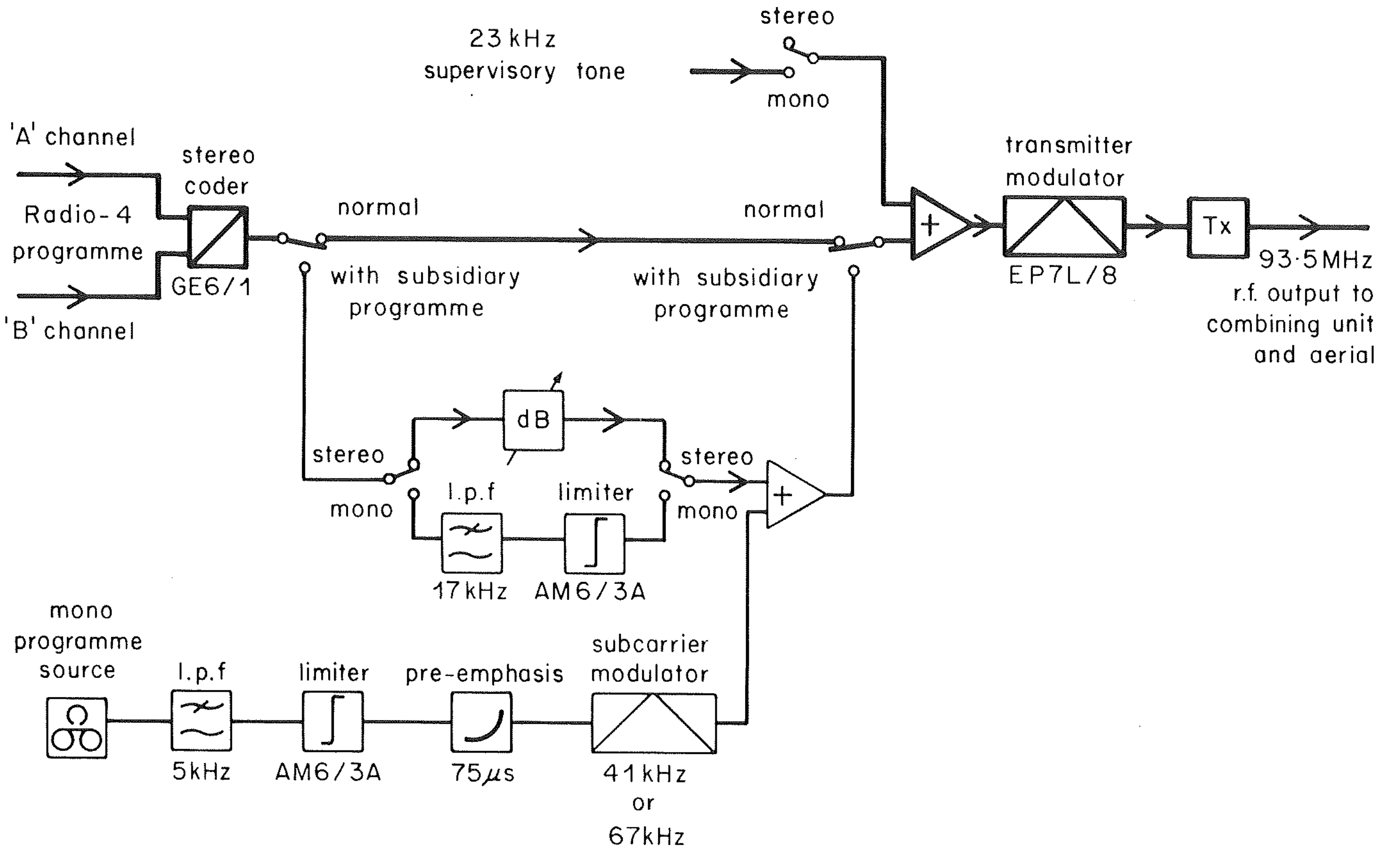

Fig. 1 - Subcarrier-injection equipment at the transmitter

TABLE 1

Sequence of Field Trials

	Frequency of sub-sidiary-channel subcarrier	Main programme	Assessment of:
First trial	41 kHz	monophonic	interference to main channel; quality of subsidiary channel
Second trial	67 kHz	monophonic	interference to main channel
Third trial	67 kHz	stereophonic	interference to main channel

times when the subcarrier was injected. In addition, during the first and second trials, each questionnaire asked for a report on main-programme reception using one of 21 battery-portable (monophonic) receivers that were circulated on loan to staff for the purpose. These receivers were circulated in order to establish the degree to which any lack of compatibility was associated with the use of particular receivers at particular sites. During the first trial, the questionnaires also asked for reports on reception of the subsidiary programme using one of 18 special subsidiary-channel receivers that were similarly circulated. In addition to making general comments, staff were asked to grade the quality of reception for all three trials according to the CCIR 5-grade quality scale:[8]

1. Bad
2. Poor
3. Fair
4. Good
5. Excellent

A typical questionnaire, completed during the first trial, is given in an Appendix (Section 9.1).

The (monophonic) programme used to modulate the subsidiary-channel subcarrier comprised typical items of speech and music. The parameters of the overall transmission system for each of the trials are listed in an Appendix (Section 9.2). For the first and second trials, when the main programme was monophonic, allowance was made for the subcarrier by introducing a limiter into the main programme chain and adjusting the limiting level to restrict the allowance for pre-emphasis of the main programme from 5 dB to 2 dB as the level of injection of the subcarrier was increased from zero to 30%. For the third trial, however, when the main programme was stereophonic, it was necessary for the main programme to be attenuated by up to 3·5 dB so as to maintain the normal stereo allowance of 2 dB for pre-emphasis at all levels of injection of the subcarrier.

For the first and second trials it was considered likely that the impairment caused by the presence of the subsidiary programme would be very slight and would be detected, to a very large extent, only by experienced listeners of the type to whom the questionnaires were supplied. It was therefore regarded as permissible to inject the subcarrier during normal programme hours.

3.2. First trial, 41 kHz subsidiary-channel subcarrier, monophonic main programme

3.2.1. Description of test

For the first field trial, the frequency of the subsidiary-channel subcarrier was 41 kHz. This frequency was chosen because it had been adopted as standard in the USA before the introduction of stereophony. It was therefore considered likely to represent the best compromise when used with a monophonic main programme.

The subcarrier was injected into the main channel of the Wrotham Radio-4 transmitter (93·5 MHz) on weekdays during the periods shown in Table 2; on the few occasions when stereophonic programmes were radiated, the tests were interrupted.

3.2.2. Results

3.2.2.1. Listener complaints

During the period 4.1.73 to 17.1.73 (7½% injection) about 8 complaints were received from the general public. During the period 18.1.73 to 16.2.73 (15% injection) about 37 further complaints were received.

The complaints, which all concerned severe distorted breakthrough of the subsidiary programme on to the main programme on certain models of stereo receivers, came from widely scattered locations. The interference was quoted as 'objectionable' and as having a 'volume practically that of normal programme'. A brief investigation on one of these stereo receivers showed that the interference occurred because, unless the receiver was manually switched to 'mono', it continued to respond to signals within the stereo difference-signal bandwidth (23 kHz to 53 kHz), despite the absence of the 19 kHz pilot tone, and that the resulting impairment was severe. Manually switching this particular receiver to mono completely removed the impairment. The same was found to be true, by the listeners, for most of the receivers complained of, but about 20% of the complainants could not manually switch their receivers to mono. Because the number of listener complaints was very much larger than was expected the trial was prematurely stopped. Since they revealed an unforeseen feature of certain stereo receivers, however, the listener complaints provided valuable information.

3.2.2.2. Subjective tests of main-programme reception

The results are summarised in Table 3. The subjective grades quoted for stereo receivers apply to normal operation of the receivers, i.e. relying on the automatic stereo/mono switching facility. Any improvement obtained by manual switching is covered in a footnote.

Different groups of staff completed questionnaires for the two levels of injection. The average grading for both groups, for reception on the listeners' own stereo and own mono receivers in the absence of the subsidiary programme, was 4·9 and 4·5 respectively; for the loaned portable receivers the corresponding average grade was 4·1.

TABLE 2

Schedule of Subcarrier Transmission Times and Injection Levels: First Trial, 41 kHz Subsidiary-Channel Subcarrier, Monophonic Main Programme

Mon. to Fri. (inclusive)		% injection during the hours			
From	To	1200 to 1400	1500 to 1700	1945 to 2015	2215 to 2245
4. 1. 73	17. 1. 73	–	–	7½%	7½%
18. 1. 73	5. 2. 73	–	–	15%	15%
6. 2. 73	9. 2. 73	15%	15%	15%	15%
12. 2. 73	13. 2. 73	–	–	15%	15%
14. 2. 73	15. 2. 73	7½%	7½%	15%	15%
16. 2. 73		–	–	15%	15%

TABLE 3

Results of Subjective Tests on Main-Programme Reception: First Trial, 41 kHz Subsidiary-Channel Subcarrier, Monophonic Main Programme

Receiver	Subcarrier injection level	No. of reports of nil impairment by subsidiary programme	Reception impaired by subsidiary programme	
			No. of Reports	Average grade
Own Stereo	7½%	14	5*	2·8
	15%	15	9**	2·8
Own Mono	7½%	29	0	–
	15%	19	2	4·0
Loaned Portable	7½%	39	2	4·0
	15%	35	14	3·4

* Of these: 4 effected a complete cure by switching to mono
1 could not effect a complete cure by switching to mono
** Of these: 2 effected a complete cure by switching to mono
1 could not effect a complete cure by switching to mono
6 could not switch to mono

It was found that the reports of impaired reception on the loaned portable receivers could not be associated with the use of particular receivers at particular sites.

There was no evidence that main-channel reception near the limit of the preferred stereo service area (approximately 1 mV/m) was worse than at locations nearer the transmitter.

3.2.2.3. Subjective tests of subsidiary-programme reception

Staff supplied with questionnaires were asked to report on the quality of reproduction of the subsidiary programme both when the subsidiary-channel receivers were used with their built-in rod aerials and when they were connected to the listeners' own domestic v.h.f. aerials.

The results are summarised in Table 4.

The impairments most frequency reported were cross-talk from the main programme, noise, restricted modulation bandwidth, and distortion. The percentages of the questionnaires on which each of these complaints occurred are given below:

		7½% injection	15% injection
(i)	cross-talk	83%	84%
(ii)	noise	63%	64%
(iii)	bandwidth	51%	46%
(iv)	distortion	9%	16%

TABLE 4

Results of Subjective Tests on Reception of Subsidiary Programme: First Trial, 41 kHz Subsidiary-Channel Subcarrier, Monophonic Main Programme

Aerial system	Subcarrier injection level	No. of reports	Average grade
Own domestic aerial	7½%	25	3·0
	15%	27	3·2
Built-in rod aerial	7½%	43	2·5
	15%	50	2·4

There was no evidence that reception of the subsidiary programme near the limit of the preferred service area was worse than at locations nearer the transmitter.

3.3. Second trial, 67 kHz subsidiary-channel subcarrier, monophonic main programme

3.3.1. Description of test

In an attempt to reduce the severe impairment caused, mainly to listeners using stereo receivers, by the introduction of a 41 kHz subcarrier, the trial described in Section 3.2 was repeated using a 67 kHz subcarrier. This is the subcarrier frequency that has now been adopted as

TABLE 5

Schedule of Subcarrier Transmission Times and Injection Levels: 67 kHz Subsidiary-Channel Subcarrier, Monophonic Main Programme

Mon. to Fri. (inclusive)		% Injection during the hours:		
From	To	13.30 to 14.00	21.45 to 22.15	19.15 to 19.45
3. 12. 73	14. 12. 73	–	7½%	7½%
17. 12. 73	21. 12. 73	–	15%	15%
31. 12. 73	11. 1. 74	–	15%	15%
14. 1. 74	1. 2. 74	15%	20%	20%
4. 2. 74	1. 3. 74	20%	30%	30%

standard for the purpose in the USA in association with a stereophonic main programme. As for the first trial, however, the subcarrier was injected only during monophonic main programmes.

The subsidiary-channel subcarrier was injected into the main channel of the same Wrotham Radio-4 transmitter (93·5 MHz) as for the first trial, on weekdays during the periods shown in Table 5; on the few occasions when the main programme was stereophonic, the tests were interrupted, as before.

Questionnaires and battery-portable receivers were issued to members of BBC staff, as for the first trial (see Section 3.1), but, since the purpose of this second trial was to assess compatibility, no assessment was made of the subsidiary-channel performance.

As before, complaints of impairment to main-programme reception received from members of the public during the periods shown in Table 5 were also noted.

3.3.2. Results

3.3.2.1. Listener complaints

No complaints were received during the period of 7½% injection. One complaint was received during the period of 15% injection and, on investigation, it was found to arise because of direct breakthrough of the subsidiary programme, caused by incorrect tuning due to a faulty tuning-indicator. Two further complaints were received during the period of 20% injection and three during the period of 30% injection. All the complaints referred to reception on fairly expensive stereo receivers and, although only the one complaint was investigated, it is believed that

TABLE 6

Reports From Questionnaires on Main-Programme Reception: 67 kHz Subsidiary-Channel Subcarrier, Monophonic Main Programme

Receiver	Subcarrier injection level	No. of reports of nil impairment by subsidiary programme		Reports of impairment by subsidiary programme, not removed by tuning adjustment	
		No comment on tuning difficulties	careful tuning needed	No. of reports	Average grade
Own Stereo	7½%	19	–	–	–
	15%	18	1	1	4
	20%	23	1	1	4
	30%	20	1	5	2·6
Own Mono	7½%	21	–	1	3·5
	15%	14	–	–	–
	20%	19	–	3	2·5
	30%	12	1	5	2·8
Loaned Portable	7½%	20	–	4	3·2
	15%	34	1	1	4
	20%	43	–	8	2·8
	30%	8	1	8	3·2

most, if not all, referred to intelligible or semi-intelligible cross-talk of the subsidiary programme on to the main programme which could at least have been reduced, if not completely removed, by careful tuning.

This number of complaints was roughly as envisaged and was considered to be sufficiently small to permit the trial to continue for its planned period.

3.3.2.2. Subjective tests of main-programme reception

The reports from the questionnaires are summarised in Table 6. As for the results given in Section 3.2.2.2, reception in the absence of the subsidiary programme, using the listeners own stereo and own mono receivers was graded 4·9 and 4·5 respectively; for the loaned portable receivers it was graded 4·1.

The great majority of the reported impairments (particularly at the higher levels of injection) were of intelligible or semi-intelligible cross-talk from the subsidiary channel that could generally be reduced in level (or removed entirely) by careful tuning. If it could be removed entirely by careful tuning it is shown in Table 6 as 'nil impairment'. Although no comment with regard to receiver tuning was specifically sought on the questionnaires, a few observers found that careful tuning was needed to remove impairment due to the subsidiary programme (see Table 6).

The reports of reception when using the portable receivers showed the impairment to depend not only upon the level of injection but also upon the use of particular receivers at particular locations. As the level of injection was increased, more of the portable receivers were found to exhibit an impairment although, in most cases, only when those particular receivers were used at particular sites.

There was no evidence that reception of the main programme near the limit of the preferred stereo service area was worse than at locations nearer the transmitter.

3.4. Third trial, 67 kHz subsidiary-channel subcarrier, stereophonic main programme

3.4.1. Description of test

The results described in Section 3.3.2 show that it would probably be acceptable to radiate a subsidiary programme from v.h.f. f.m. transmitters, using a 67 kHz subcarrier, provided the main-channel programme were monophonic. It was therefore decided to conduct a further brief trial to assess its effect with a stereophonic main programme. Because it was thought likely to imapir reception for many listeners, however, the tests were performed only after programme close-down.

The stereophonic main programme used for the tests comprised an orchestral item followed by items of dramatic speech. The test transmissions were radiated from the same Wrotham Radio-4 transmitter (93·5 MHz) as for the previous trials, from about 0030 to 0100 hours on 6th and 7th June 1975. Each transmission comprised six tests, for which the modulation conditions were all identical but for which various levels of injection of the subsidiary-channel subcarrier, from zero to 30%, were adopted.

As for the first and second trials (see Section 3.1), questionnaires were supplied to members of BBC staff who were asked to report on reception of the main programme using their home receivers. Reception was also assessed using twelve current-model stereo receivers that were borrowed for the purpose. Ten of the receivers were borrowed from five UK manufacturers. The other two were products of a manufacturer in the USA and were included because it was considered desirable to include commercial receivers that had been designed for use in the presence of a subsidiary-channel service of the type being tested; such receivers were not available from UK manufacturers. No assessment of subsidiary-channel performance was made during this third field trial.

3.4.2. Results

The impairment caused by the subsidiary-channel subcarrier to reception on monophonic receivers was expected to be similar for both monophonic and stereophonic main-channel programmes. Although far fewer questionnaires were returned relating to reception on monophonic receivers than on stereophonic receivers, that expectation was confirmed. The following therefore deals only with the use of stereophonic receivers.

The results are summarised in Table 7. The average subjective grading in the absence of the subsidiary programme was 4·6.

TABLE 7

Reports From Questionnaires on Stereo Main-Programme Reception: 67 kHz Subsidiary-Channel Subcarrier, Stereophonic Main Programme

Receiver	Subcarrier injection level	No. of reports of nil impairment by subsidiary programme	Reception impaired by subsidiary programme	
			No. of reports	Average grade
Own Stereo	7½%	27	29	2·7
	15%	19	37	2·5
	20%	17	39	2·1
	30%	16	40	1·9

The reported impairments were mainly of 'birdies', 'sizzling', 'swishing' etc. rather than intelligible breakthrough of the subsidiary programme. A few listeners reported that the receivers required careful tuning in order to avoid intelligible breakthrough.* If the receivers that were suffering impairment could be manually switched to 'mono', this effected a complete cure in the majority of cases; not all the stereo receivers, however, had that facility. The results given in Table 7 refer only to normal stereo reception.

The performances of the two American receivers were not found to be markedly better than those of the UK receivers.

It appeared that features of receiver design other than the provision of 'storecasting traps'** affected the receiver performance. Some receivers fitted with traps were still subject to interference to stereo reception, for example, whereas other receivers, without traps, were immune.

4. Discussion of results

4.1. Compatibility, main-channel performance

When using a 41 kHz subcarrier for the subsidiary programme, reception of a monophonic main programme was in many cases seriously impaired, particularly when using stereophonic receivers. During the period of 7½% injection, listener complaints were received at an average rate of 0·8 per day; 26% of the questionnaires relating to reception on stereo receivers reported severe impairment (mean grade 2·8). During the period of 15% injection those figures increased to 1·7 listener complaints per day and 37% of stereo questionnaires reporting severe impairment (mean grade 2·8). These figures represented a significant increase in the number of legitimate complaints normally received from listeners and thus, as stated in Section 3.2.2.1, the trial was prematurely stopped.

Increasing the frequency of the subcarrier to 67 kHz (and retaining a monophonic main programme) largely removed the impairment for injection levels up to 15% provided that, in a small proportion of cases, the receivers were tuned carefully. During the fifteen-day period of 15% injection, for example, only one listener complaint was received and, on the questionnaires, impairment was reported for only 5% of stereo receivers and for 3% of mono receivers.*** Furthermore, such reported impairments were slight. At the higher levels of injection (i.e. 20% and 30%) an increase occurred in both the number of listener complaints (3 at 30% injection) and the proportion of questionnaires reporting impairment (20% of stereo listeners at 30% injection).

It therefore appears that, if a 67 kHz subcarrier were used, 15% could be regarded as the maximum level of injection that would be acceptably compatible with reception of a monophonic main-channel programme on current monophonic and stereophonic receivers. The results of brief subjective tests implied that, with this injection level, the accepted protection ratios for co-channel and adjacent-channel interference in a stereophonic service[9] would provide adequate mutual protection between the monophonic main-channel programme associated with the subsidiary-programme system and the stereophonic programme of a co-channel or adjacent-channel signal. The same ratios would also provide sufficient protection to the subsidiary-channel programme, except at 100 kHz carrier-frequency separation. At that separation, the protection ratio would need to be increased by about 10 dB (i.e. from 33 dB to about 43 dB). That protection ratio would need to be still further increased if a level of injection of the subsidiary-channel subcarrier less than 15% were adopted.

When the 67 kHz subcarrier was radiated with a stereophonic main programme, the serious incompatibility (with main-programme reception on stereo receivers) returned. Even at the lowest level of injection (7½%), severe imapirment to reception occurred in the case of more than 50% of stereo receivers. As the level of injection was increased, more receivers became affected until, with 30% injection, severe impairment occurred with more than 70% of stereo receivers.

Although the aspects of receiver design that caused impaired reception were not studied, it was evident from the behaviour of various types of receiver that, rather surprisingly, the provision of a storecasting trap was neither necessary nor sufficient in order to avoid impairment. If a design study is required, attention should perhaps be paid to non-uniformity of the phase/frequency characteristics of the i.f. filters, the dynamic performance of the limiter, the linearity and bandwidth of the discriminator characteristic (and correct operation of a.f.c.) and, for switching decoders, the need for a symmetrical switching action (i.e. with unity mark-to-space ratio). There was at least one example of an inexpensive stereo receiver having good compatibility, but unless the reasons are better understood it would be unwise to consider the design problem solved.

4.2. Subsidiary-channel performance

The assessments of subsidiary-channel performance (when using a 41 kHz subcarrier) were substantially the same for both 7½% and 15% injection. This is a surprising result since the two types of impairment most frequently commented upon (viz. crosstalk and noise) would both be expected to be about one grade worse at the lower injection level. The average assessment was 'fair' when using the listeners' own domestic v.h.f. aerial but only 'poor-to-fair' when using the subsidiary-programme receivers' built-in rod aerial. Both were inferior to the average assessment for the battery portable receivers, whose quality of reproduction in the absence of the subsidiary-channel subcarrier was generally assessed as 'good'.

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* If the impairment could be removed entirely by careful tuning it is shown in Table 7 as 'nil impairment'.

** i.e. post-discriminator notch filters tuned to reject the subsidiary-channel subcarrier.

*** It is true that larger proportions of the questionnaires reported impairments during the period of 7½% injection but a study showed them to be slight and to take several forms (e.g. 'buzzing', 'crackles', 'noise'). It was considered likely that few of them were caused by the presence of the subcarrier.

No assessment was made of subsidiary-channel reproduction when using a 67 kHz subcarrier because, with that subcarrier frequency, the design and performance of subsidiary-channel receivers could depend upon whether the main-channel programme were monophonic or stereophonic. If the main-channel programme were stereophonic, the filtering requirements for the subsidiary-channel of the receiver would need to be very exacting in order to ensure adequate suppression of interference from the main-channel programme. Assuming a simple filter of reasonable cost, this could otherwise be achieved only by restricting the deviation of the subsidiary-channel subcarrier and/or the higher modulating frequencies of the subsidiary programme. If, on the other hand, the main-channel programme were monophonic, interference that the subsidiary programme might cause could be adequately suppressed using a filter of reasonable cost whilst also allowing both greater subcarrier deviation and a better high-frequency response for the subsidiary programme.

Although no assessment of the subsidiary-channel performance was made when using a 67 kHz subcarrier, it is considered likely that, if the main programme were stereophonic, the quality of reproduction of the subsidiary programme would be similar to that reported during the first field trial (see Section 3.2.2.3). If it were agreed, however, that the subsidiary programme would be broadcast only when the main programme were monophonic, it is possible that receivers could be designed that would provide better-quality reproduction of the subsidiary programme. This would, however, be considered as a great limitation in the planning of our v.h.f. services.

Based on the limited work carried out on reception of the subsidiary channel it is estimated that its service area would lie between the limits of the monophonic and stereophonic service areas of the main programme.

5. Considerations affecting a possible future subsidiary-programme service

If the inauguration of a subsidiary-programme service needs to be considered in the future, with either a monophonic or a stereophonic main programme, the following factors may need to be borne in mind.

(i) The foregoing results suggest that the use of a subcarrier frequency of about 67 kHz strikes the best compromise with regard to compatibility on the one hand and signal-to-noise ratio, cross-talk, and adjacent-channel interference in the subsidiary channel on the other. Given that frequency for the subcarrier, the bandwidth available for the subsidiary channel is such that frequency-modulation as used in the tests would appear to be the most suitable type of modulation for the subsidiary-channel subcarrier. It is probable that the use of a compandor would slightly improve the signal-to-noise-and-cross-talk ratios of the subsidiary channel but, since its use would increase the average modulation level of the subsidiary channel, the improvement would be gained at the expense of cross-talk into the main channel. Thus it appears unlikely that any material overall improvement could be gained by changing the system parameters from those listed in the Appendix (Section 9.2).

(ii) The effect that the presence of the subsidiary channel may have on the maximum permissible reflection coefficient of the transmitting aerial should also be considered. Reflection at the aerial has an effect equivalent to multipath propagation and, depending upon the magnitude of the aerial reflection coefficient and the delay in the feeders, it may cause cross-talk, in all receivers, between the main and the subsidiary programmes. The transmitting aerial at Wrotham, as used for the tests described in this Report, is not representative in that respect because it was matched to a very early specification (that was drawn up before typical receiver performances were known) and it has a particularly small reflection coefficient.[10] The majority of the other BBC v.h.f. f.m. transmitting aerials were matched to a slightly-relaxed specification[11] that was based on the performance of early f.m. receivers, many of which, at that time, had poor limiters. More recently, f.m. receivers with good limiters have become commonplace and it has now become permissible to adopt an even more-relaxed specification. It may be that, although the specification given in Reference 11 would be acceptable for transmissions that include a subsidiary programme, the later specification might require review.

(iii) Difficulties might arise if the present stereophonic service is extended to provide quadraphony in the future. For example, some form of signalling might be needed in order to activate features of quadraphonic receivers when quadraphonic information is present. The means proposed for this to date involves the introduction of one or more subcarriers at either the third-harmonic, fourth-harmonic or fifth-harmonic frequency of the pilot tone (viz. 57 kHz, 76 kHz or 95 kHz).[12] The level of injection of such subcarriers would probably be low enough not to affect the results described in this Report but the possibility of their presence should be borne in mind.

6. Conclusions

This Report has shown that the addition of a subsidiary programme to an existing v.h.f. f.m. broadcasting service would, at best, cause slight impairment to reproduction of the main programme when using existing receivers. The quality of reproduction of the subsidiary programme would be markedly inferior to that of the main programme. As disucssed in Section 5, it is considered unlikely that any worthwhile improvement could be gained by changing the parameters of the system from those tested. Both the degree of impairment caused to reproduction of the main programme, and the overall quality of reproduction of the subsidiary programme, depend upon whether the main programme is monophonic or stereophonic.

Subject to the need for somewhat greater care when tuning, the addition of a subsidiary programme, using a

67 kHz subcarrier with not more than 15% injection, would appear to be acceptably compatible with reception of a monophonic main programme on current monophonic and stereophonic receivers. It would, however, be grossly incompatible with reception of a stereophonic main programme on the majority of current stereophonic receivers, even at the lowest level of injection that would be acceptable for a subsidiary-programme service. Since suitable f.m. receivers can be made economically, it could be anticipated that, at some suitably distant date, a stereo-compatible subsidiary service could be provided.

Providing sufficient incentive to ensure that the next generation of receivers are all suitable for storecasting could be difficult.

It should be noted that features of receiver design other than the provision of a storecasting trap (as discussed in Section 4.1) appear to be important in providing immunity to impairment by the subsidiary programme.

For the reasons discussed in Section 4.2, the quality of reproduction of the subsidiary programme would depend upon whether the main programme were monophonic or stereophonic. If the option to transmit either monophonic or stereophonic main programmes is to be retained, the selectivity of the subsidiary-programme receiver must, with present filter technology, be such as to severely degrade the quality of reproduction of the subsidiary programme. If, however, a subsidiary-programme service were inaugurated on the understanding that it would be broadcast only during monophonic main programmes, receivers could be designed that would provide better-quality reproduction of the subsidiary programme although, most probably, still markedly inferior to that of the main programme. If that course were adopted, however, it would need to be adhered to for the foreseeable future because subsidiary-programme receivers that made the most of a monophonic system would become virtually unusable if the main programme subsequently became stereophonic.

It would seem that if it is decided that a subsidiary programme should be broadcast using these techniques, while keeping open the option of transmitting a stereophonic main programme ultimately, the following steps would be necessary:

1. Commit the parent channel to monophonic broadcasting during the periods when the subsidiary signal is being transmitted. Accept the limitations in programme planning which would follow from this.

2. Launch a 'normal hours' monophonic experimental service in order to check transmitters and receivers and carry out more complete tests on subsidiary-channel quality.

3. Announce the intention of changing the main channel to stereo at an undisclosed date. To assist the design of new receivers* initiate, with the co-operation of trade associations, regular trade tests of subsidiary-channel broadcasting with a stereo main signal.

These steps represent a considerable burden for the broadcaster, their audience and the receiver industry.

A small section of the audience will suffer a degraded main-channel performance or will buy new receivers. The new subsidiary-channel receiver may be expensive.

The receiver industry will have to reconsider the main-channel receiver design and produce a new design of subsidiary-channel receiver for a limited market.

With this in mind it will be necessary to consider alternatives, such as whether sufficient bandwidth can be made available for conventional broadcasting. It is not however appropriate to consider these questions in this report. It is however reasonable to recommend that, should it be felt desirable to introduce a new subsidiary service, the way should be kept clear ultimately to restore stereo broadcasting on all main channels. With this in mind step (3) is of particular importance.

7. Acknowledgements

The assistance given by the BBC Operational Staff who operated the equipment at the Wrotham transmitting station, and by the many members of staff who completed the questionnaires, is gratefully acknowledged.

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9. Appendix

9.1. Typical completed questionnaire

FIELD TEST OF F.M. SUBCARRIER TRANSMISSION SYSTEM: WROTHAM, 1972/73

QUESTIONNAIRE

Name: J. Smith

Address: Chesham, Bucks.

Please assess grade of reception on the CCIR 5-point quality scale:—

5 = Excellent
4 = Good
3 = Fair
2 = Poor
1 = Bad

IMPORTANT

NOTE THAT THIS DIFFERS FROM SOME PREVIOUSLY-USED SCALES INSOFAR THAT "EXCELLENT" IS "5", AND "BAD" IS "1".

1. Reception of subcarrier programme, using built-in rod aerial on receiver.

Day: Thurs. Date: 4/1/73 Time: from 19.45 to 20.15

Receiver No. S 14

Grade of Reception	Remarks
2	Restricted bandwidth giving muffled effect not normally associated with f.m. Noise level high, even with rod aerial fully-extended. Receiver in ground-floor room.

2. Reception of main-channel programme using loaned portable receiver with built-in rod as the aerial (no external aerial).

Day: Thurs. Date 4/1/73 Time: from 19.45 to 20.15

Receiver No. P 19

Grade of Reception when subcarrier ON	Remarks
4	Some background hiss, otherwise satisfactory.

Day: Thurs. Date: 4/1/73 Time: from 19.30 to 19.45

Receiver No. P.19

Grade of Reception when subcarrier OFF	Remarks
4	As when subcarrier on.

3. Reception of subcarrier programme, using separate aerial. (To be completed if you have a Band II aerial that can be connected to the subcarrier receiver.)

Type and position of aerial: 3-element, on chimney stack, 27ft. a.g.l.

Day: Thurs. Date: 4/1/73 Time: from 19.45 to 20.15

Receiver No. S 14

Grade of Reception	Remarks
3	Restricted bandwidth as before. Noise level better than with rod aerial but worse than for normal stereo reception.

4. Reception of main-channel programme using your own v.h.f. f.m. receiver.

Make: [illegible] Model No. [illegible] (See footnote)

Type and position of aerial: As above

Day: Thurs. Date: 4/1/73 Time from 19.45 to 20.15

Grade of Reception when subcarrier ON	Remarks
5	With mono button pressed.
3	With mono button not pressed, audible crosstalk from subcarrier channel.

If this is a stereo receiver, can it be manually switched to mono?

Yes ☑

No ☐

Please tick as appropriate, or leave blank if mono receiver

If 'Yes', please comment on reception for both 'mono' and 'stereo' positions of this switch, both above and on page 3.

Day: Thurs. Date: 4/1/73 Time: from 19.30 to 19.45

Grade of Reception when subcarrier OFF	Remarks
5	Nil.

9.2. System parameters

9.2.1. First trial, 41 kHz subsidiary-channel subcarrier, monophonic main programme

Main-carrier frequency:	93·5 MHz (Radio-4)
Subcarrier frequency:	41 kHz
Peak deviation of subcarrier by subsidiary-channel programme: (no allowance for pre-emphasis)	±6 kHz
Supervisory tone frequency:	23 kHz
Modulation processing:	

Main channel: in accordance with standard BBC procedure for v.h.f. transmitters fed by a p.c.m. link, but with a 17 kHz low-pass filter and a limiter type AM6/3A (with 'flat' side-chain) operating in 'limit' mode added, both at the output of the station stereo coder, GE6/1. The limiting level of the AM6/3A was set, so as to restrict the allowance for pre-emphasis, depending upon the level of subcarrier injection, see below.

Pre-emphasis time-constant: 50 μs.

Subsidiary channel: modulation bandwidth-restricted to 5 kHz, limited by AM6/3A operating in 'limit' mode, with pre-emphasised side-chain, prior to pre-emphasis.

Pre-emphasis time-constant: 75 μs.

Level of injection	0	7½%	15%
Allowance for pre-emphasis:	5·3 dB	4·6 dB	3·8 dB
Deviation (kHz) of main carrier by:			
Main programme,			
100% mod. at low frequencies:	± 38·40	± 38·40	± 38·40
Allowance for pre-emphasis:	± 32·10	± 26·48	± 20·85
Subcarrier:	0	± 5·62	± 11·25
Supervisory tone: (23 kHz)	± 4·50	± 4·50	± 4·50
Totals, kHz	± 75·00	± 75·00	± 75·00

9.2.2. Second trial, 67 kHz subsidiary-channel subcarrier, monophonic main programme

Main-carrier frequency:	93·5 MHz (Radio-4)
Subcarrier frequency:	67 kHz
Peak deviation of subcarrier by subsidiary-channel programme: (no allowance for pre-emphasis)	±6 kHz
Supervisory tone frequency:	23 kHz
Modulation processing:	

Main channel: in accordance with standard BBC procedure for v.h.f. transmitters fed by a p.c.m. link, but with a 17 kHz low-pass filter and a limiter type AM6/3A (with 'flat' side-chain) operating in 'limit' mode added, both at the output of the station stereo coder, GE6/1. The limiting level of the AM6/3A was set, so as to restrict the allowance for pre-emphasis, depending upon the level of subcarrier injection, see below.

Pre-emphasis time-constant: 50 μs.

Subsidiary channel: modulation bandwidth-restricted to 5 kHz, limited by AM6/3A operating in 'limit' mode, with pre-emphasised side-chain, prior to pre-emphasis.

Pre-emphasis time-constant: 75 μs.

Level of injection:	0	7½%	15%	20%	30%
Allowance for pre-emphasis:	5·3 dB	4·6 dB	3·8 dB	3·2 dB	1·9 dB
Deviation (kHz) of main carrier by:					
Main programme,					
100% mod. at low frequencies:	± 38·40	± 38·40	± 38·40	± 38·40	± 38·40
Allowance for pre-emphasis:	± 32·10	± 26·48	± 20·85	± 17·10	± 9·60
Subcarrier:	0	± 5·62	± 11·25	± 15·00	± 22·50
Supervisory tone (23 kHz)	± 4·50	± 4·50	± 4·50	± 4·50	± 4·50
Totals, kHz	± 75·00	± 75·00	± 75·00	± 75·00	± 75·00

9.2.3. Third trial, 67 kHz subsidiary-channel subcarrier, stereophonic main programme

Main-carrier frequency: 93·5 MHz (Radio-4)
Subcarrier frequency: 67 kHz
Peak deviation of subcarrier by subsidiary-channel programme:
(no allowance for pre-emphasis) ±6 kHz
Modulation processing:

Main channel: in accordance with standard BBC procedure for v.h.f. transmitters fed with stereo programme by a p.c.m. link but reducing the deviation that corresponded to 100% modulation at low frequencies, depending upon the level of subcarrier injection, so as to maintain 2 dB allowance for pre-emphasis (see below).

Pre-emphasis time-constant: 50 μs.

Subsidiary channel: modulation-bandwidth restricted to 5 kHz, limited by AM6/3A operating in 'limit' mode, with pre-emphasised side-chain, prior to pre-emphasis.

Pre-emphasis time-constant: 75 μs.

Level of injection:	0	7½%	15%	20%	30%
Allowance for pre-emphasis:	2 dB	2 dB	2 dB	2 dB	2 dB
Atten. of main-channel prog.:	0 dB	0·7 dB	1·6 dB	2·2 dB	3·5 dB
Deviation (kHz) of main carrier by:					
Main programme,					
100% mod. at low frequencies:	± 54·21	± 49·75	± 45·28	± 42·30	± 36·34
Allowance for pre-emphasis:	± 14·04	± 12·88	± 11·72	± 10·95	± 9·41
Pilot tone:	± 6·75	± 6·75	± 6·75	± 6·75	± 6·75
Subcarrier:	0	± 5·62	± 11·25	± 15·00	± 22·50
Totals, kHz	± 75·00	± 75·00	± 75·00	± 75·00	± 75·00

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